1974
USDA FOREST SERVICE RESEARCH PAPER PNW-182

INFLUENCE OF FERTILIZER NITROGEN SOURCE on deer browsing and chemical composition of nursery-grown Douglas-fir

M. A. Radwan
G. L. Crouch
W. D. Ellis

PACIFIC NORTHWEST FOREST AND RANGE EXPERIMENT STATION
FOREST SERVICE U.S DEPARTMENT OF AGRICULTURE PORTLAND, OREGON

ABSTRACT

Effects of nursery fertilization of year-old Douglas-fir seedlings with ammonium sulfate, calcium nitrate, and urea on browsing by black-tailed deer, and chemical properties were compared. Fertilizers were applied at 56 kg N/ha in May and again in September, and seedlings were harvested in November. Seedlings from the different treatments were equally browsed by penned deer. Chemical analyses of shoots indicated significant differences due to N source only in manganese and sulfur contents. However, the larger size of urea- and nitrate-fertilized plants indicated that their shoots contained higher quantities of the majority of the chemicals determined.

Keywords: Douglas-fir, *Pseudotsuga menziesii*, browse, deer, chemical analysis.

Expanding reforestation with Douglas-fir (*Pseudotsuga menziesii* (Mirb.) Franco) requires intensive management of Pacific Northwest forest tree nurseries. In such management, fertilization, especially with nitrogen, is increasingly important. Although amounts of nitrogen applied by nurseries in the region are based upon the fertility of nursery soils, choice of nitrogen source has been largely empirical.

The form of nitrogen supply greatly affects both growth and chemical composition of conifer seedlings of several species (Pharis et al. 1964, Durzan and Steward 1967, McFee and Stone 1968, Christersson 1972). Such effects in nursery stock could substantially influence success of regeneration, especially if deer browsing preference for seedlings is changed by different fertilization regimes.

Information on effects of nitrogen sources on Douglas-fir seedlings is limited and contradictory. In British Columbia, seedlings showed greater growth response to ammonium than to nitrate in one study (van den Driessche 1971), but grew better with nitrate than with ammonium in another (Krajina et al. 1972). In western Washington, on the other hand, we recently found that seedling growth in the nursery and outplanting performance of trees fertilized with nitrate and urea were similar and superior to those of trees fertilized with ammonium (Radwan et al. 1971). In addition, there are no reports in the literature on effects of different forms of nitrogen on deer browsing preference for, or detailed chemical composition of, Douglas-fir seedlings.

This study, therefore, is a further investigation of effects of nursery fertilization of Douglas-fir with ammonium sulfate, calcium nitrate, and urea on chemical properties and browsing preference by black-tailed deer (*Odocoileus hemionus columbianus*). We used seedlings from our earlier study (Radwan et al. 1971). Also, we limited chemical analysis to the tips of the seedlings since these are the tissues normally browsed by deer and because it is generally agreed that shoot tips provide a good basis for assessing the nutrient status of Douglas-fir.

MATERIALS AND METHODS

Douglas-fir seedlings were grown and fertilized at the Webster Nursery in western Washington as previously outlined (Radwan et al. 1971). Briefly, three fertilizers (ammonium sulfate, calcium nitrate, and urea) were applied to 1-year-old seedlings in nine beds. Design included three replications per treatment, with treatments assigned at random. Fertilizers were broadcast at 56 kg N/ha in May and again in September, and seedlings were harvested in November. To balance treatments as much as possible, seedlings of the ammonium sulfate and urea treatments received the assigned nitrogen fertilizer plus calcium sulfate containing calcium equivalent to that in the calcium nitrate treatment. At harvest, randomly selected trees from each treatment were lifted by hand and used for subsequent determinations of deer preference and chemical properties. At that time, shoots of seedlings from the calcium nitrate and urea treatments were significantly larger than those from the ammonium sulfate treatment (Radwan et al. 1971).

Deer preference was tested in a 1-ha enclosure located near the nursery and maintained by the U. S. Bureau of Sport Fisheries and Wildlife. During the test, the enclosure contained a stand of orchardgrass (*Dactylis glomerata*), commercial pelleted ration, and seven

2/ [Injuries]

black-tailed deer. Test seedlings, 100 from each treatment, were exposed to voluntary feeding by the deer in a randomized block design (Dodge et al. 1967). Treatments were replicated in 10 blocks, and seedlings were planted to uniform height at 1- by 1-m spacing within blocks. Inspections for browsing evidence were made daily until all test seedlings were browsed. A tree was considered browsed if any portion of it was removed by deer; only the first browsing was recorded. Relative preference was determined by comparing percent browsing among treatments periodically during the test and days of exposure required for complete browsing.

Chemical analyses for each replication were carried out in duplicate on tissues composited from 240 seedlings. Samples were taken by clipping the top 5 cm of the terminal and two lateral shoots of each seedling. The fresh tissue was chopped into small pieces and thoroughly mixed. Subsamples were taken for determination of moisture, pH, and titratable acidity. Remaining tissue was dried to constant weight at 65° C, ground to 40 mesh in a Wiley mill, and stored in sealed containers at -15° C until analyzed.

Moisture was determined by drying to constant weight at 65° C, and ash in the ground tissue was estimated in platinum crucibles at 500° to 550° C. Titratable acidity and pH were determined on centrifuged aqueous extracts of the fresh tissue by titration with standard alkali and use of a pH meter with a glass electrode (Horwitz 1970). Total available carbohydrates were extracted and hydrolyzed with 0.2 N H_2SO_4 (Smith et al. 1964) and resulting sugars were estimated as glucose (Hassid 1937). Analyses of other tissue components were made as follows: potassium and sodium by flame photometer, calcium by a titrimetric method, and total and soluble nitrogen by micro-Kjeldahl procedure (Horwitz 1970); magnesium, iron, and manganese by the magnesium ammonium phosphate titrimetric method, O-phenanthroline colorimetric method, and the colorimetric periodate procedure, respectively (Chapman and Pratt 1961); phosphorus according to Fiske and Subbarow (1925); chlorine, as chloride, by a modification of the Volhard method (Caldwell and Moyer 1935); and sulfur by a turbidimetric technique modified from Butters and Chenery (1959).

STATISTICAL ANALYSIS

Data were subjected to analysis of variance, and means were separated according to Tukey's test as required (Snedecor 1961).

RESULTS AND DISCUSSION

Deer Preference

Browsing of test seedlings began almost immediately; but from the start, no pattern of preference among nitrogen sources was detected. Day-to-day tabulations showed one treatment ahead one day and behind the next. Analysis of variance at 5-day intervals similarly revealed no significant differences among treatments during the 30-day exposure period. Largest difference occurred at 10 days when cumulative browsing of seedlings from the ammonium sulfate, urea, and calcium nitrate treatments were 70, 76, and 68 percent, respectively. A second comparison, using the mean number of exposure days until all seedlings were browsed (Dimock 1971), also detected no significant differences among treatments. Averages used in this analysis were 9.6, 9.6, and 10.7 days to complete browsing for ammonium, urea, and nitrate nitrogen sources, respectively.

These results indicate that plantations of Douglas-fir seedlings would be equally susceptible to deer browsing regardless of the source of the N applied in the nursery. In the test, planting heights were carefully controlled since it has been recently shown that deer browse taller seedlings more readily than shorter ones among groups of similar-aged trees (Dimock 1971).

Chemical Properties

Since deer preference for treated seedlings was an important part of this study, concentrations of all chemical constituents are expressed on a fresh-weight basis to allow comparison of levels as the animal encounters them in feeding. Trends in the results, however, do not change when the data are calculated on a dry-weight basis.

Chemical properties of seedling shoot tips (table 1) were affected less by nitrogen source than indicated by differences in growth between the seedlings (Radwan et al. 1971). Significant differences due to treatment were detected only in two properties. Manganese concentration was higher in the shoots of ammonium-fed seedlings than in shoots of the other

Table 1.--*Chemical properties of fresh foliage of Douglas-fir seedlings fertilized with different sources of nitrogen in the nursery*

Property	Unit of measure	Nitrogen treatment[1/]		
		Ammonium sulfate	Calcium nitrate	Urea
Moisture	percent	61.83 a	63.06 a	62.83 a
H-ion concentration	pH units	4.38 a	4.29 a	4.35 a
Titratable acidity	ml .1N-NaOH per 100 g	78.07 a	79.61 a	77.80 a
Total available carbohydrates	percent	6.12 a	5.78 a	5.87 a
Ash	percent	1.13 a	1.05 a	1.08 a
Total nitrogen	percent	.48 a	.47 a	.48 a
Soluble nitrogen	ppm	410 a	386 a	392 a
Calcium	ppm	2060 a	1980 a	2110 a
Potassium	ppm	1100 a	1333 a	1167 a
Sodium	ppm	20 a	16 a	17 a
Magnesium	ppm	610 a	540 a	560 a
Iron	ppm	38 a	34 a	35 a
Manganese	ppm	174 a	103 b	115 b
Phosphorus	ppm	790 a	730 a	764 a
Chlorine	ppm	112 a	91 a	93 a
Sulfur	ppm	284 a	191 c	224 b

[1/] Fertilizers were applied to the seedlings in the nursery at 56 kg N/ha in May and again in September and seedlings were lifted in November. Values are averages of three composite samples, and means within each chemical property followed by the same letter do not differ significantly at the 5-percent level. To convert values of the last 13 components to dry-weight basis, multiply by 2.62, 2.71, and 2.69 for ammonium sulfate, calcium nitrate, and urea plants, respectively.

two treatments, and percentage sulfur was highest in the ammonium-cultured plants and lowest in those which received nitrate. However, because of smaller dry weights of shoots of ammonium plants (Radwan et al. 1971), absolute amounts of manganese and sulfur in the tops were approximately the same for all treatments.

Higher sulfur percentages in the ammonium and urea shoots may be due to increased uptake of sulfates added to the soil of these two treatments. Likewise, induced acidity in soil by ammonium sulfate probably increased availability of manganese to the ammonium plants. Resulting higher manganese content in shoots of these plants, however, was still within the range reported for needles of Douglas-fir nursery stock (Krueger 1967), and it is doubtful that it was sufficient to exert toxic effects.

Lack of differences among treatments in remaining chemical properties was unexpected. Differences in one or more of these properties due to N form have been shown earlier by other investigators in Douglas-fir (van den Driessche 1971) and other conifers (Pharis et al. 1964, McFee and Stone 1968, Christersson 1972). However, concentration data are always subject to dilution by growth, and results based upon comparisons of concentrations vary with the magnitude of growth differences among treatments. Similar concentration data for most chemical components obtained here, therefore, resulted from the large difference in growth between the urea and nitrate plants and those from ammonium. The same difference, on the other hand, indicates that shoots of the urea and nitrate seedlings contained higher quantities of the majority of the chemicals determined, reflecting increased absorption and utilization of mineral nutrients by these plants compared with those from ammonium.

There was no evidence that plant shoots varied in pH or in total acidity due to treatment. Kirkby and Mengel (1967), however, noted differences in pH and in organic acid content in tomato plants due to the form of N supply in nutrient solution.

LITERATURE CITED

Butters, B., and E. M. Chenery
1959. A rapid method for the determination of total sulphur in soils and plants. Analyst 84: 239-245.

Caldwell, John R., and Harvey V. Moyer
1935. Determination of chloride. A modification of the Volhard method. Ind. Eng. Chem. (Anal. Ed.) 7: 38-39.

Chapman, Homer D., and Parker F. Pratt
1961. Methods of analysis for soils, plants, and waters. 309 p. Div. Agric. Sci., Univ. Calif.

Christersson, Lars
1972. The influence of urea and other nitrogen sources on growth rate of Scots pine seedlings. Physiol. Plant. 27: 83-88.

Dimock, Edward J., II
1971. Influence of Douglas-fir seedling height on browsing by black-tailed deer. Northwest Sci. 45: 80-86.

Dodge, W. E., C. M. Loveless, and N. B. Kverno
1967. Design and analysis of forest-mammal repellent tests. For. Sci. 13: 333-336.

Durzan, D. J., and F. C. Steward
1967. The nitrogen metabolism of *Picea glauca* (Moench) Voss and *Pinus banksiana* Lamb as influenced by mineral nutrition. Can. J. Bot. 45: 695-710.

Fiske, C. H., and Y. Subbarow
1925. The colorimetric determination of phosphorus. J. Biol. Chem. 66: 375-400.

Hassid, W. Z.
1937. Determination of sugars in plants by oxidation with ferricyanide and ceric sulfate titration. Ind. Eng. Chem. (Anal. Ed.) 9: 228-229.

Horwitz, William (Ed.)
1970. Official methods of analysis of the Association of Official Analytical Chemists. 11th ed., 1015 p. Assoc. Off. Anal. Chem., Washington, D.C.

Kirkby, E. A., and K. Mengel
1967. Ionic balance in different tissues of the tomato plant in relation to nitrate, urea, or ammonium nutrition. Plant. Physiol. 42: 6-14.

Krajina, V. J., S. Madoc-Jones, and G. Mellor
1972. Ammonium and nitrate in the nitrogen economy of some conifers growing in Douglas-fir communities of the Pacific North-west of America. Soil. Biol. Biochem. 5: 143-147.

Krueger, Kenneth W.
1967. Foliar mineral content of forest- and nursery-grown Douglas-fir seedlings. USDA For. Serv. Res. Pap. PNW-45, 12 p. Pac. Northwest For. & Range Exp. Stn., Portland, Oreg.

McFee, W. W., and E. L. Stone, Jr.
1968. Ammonium and nitrate as nitrogen sources for *Pinus radiata* and *Picea glauca*. Soil. Sci. Soc. Am. Proc. 32: 879-884.

Pharis, Richard P., Robert L. Barnes, and Aubrey W. Naylor
1964. Effects of nitrogen level, calcium level and nitrogen source upon the growth and composition of *Pinus taeda* L. Physiol. Plant. 17: 560-572.

Radwan, M. A., G. L. Crouch, and H. S. Ward
1971. Nursery fertilization of Douglas-fir seedlings with different forms of nitrogen. USDA For. Serv. Res. Pap. PNW-113, 8 p. Pac. Northwest For. & Range Exp. Stn., Portland, Oreg.

Smith, Dale, G. M. Paulsen, and C. A. Raguse
1964. Extraction of total available carbohydrates from grass and legume tissue. Plant. Physiol. 39: 960-962.

Snedecor, George W.
1961. Statistical methods applied to experiments in agriculture and biology. 534 p. Ames: Iowa State Univ. Press.

van den Driessche, R.
1971. Response of conifer seedlings to nitrate and ammonium sources of nitrogen. Plant & Soil 34: 421-439.

The mission of the PACIFIC NORTHWEST FOREST AND RANGE EXPERIMENT STATION is to provide the knowledge, technology, and alternatives for present and future protection, management, and use of forest, range, and related environments.

Within this overall mission, the Station conducts and stimulates research to facilitate and to accelerate progress toward the following goals:

1. Providing safe and efficient technology for inventory, protection, and use of resources.
2. Development and evaluation of alternative methods and levels of resource management.
3. Achievement of optimum sustained resource productivity consistent with maintaining a high quality forest environment.

The area of research encompasses Oregon, Washington, Alaska, and, in some cases, California, Hawaii, the Western States, and the Nation. Results of the research will be made available promptly. Project headquarters are at:

Fairbanks, Alaska
Juneau, Alaska
Bend, Oregon
Corvallis, Oregon
La Grande, Oregon
Portland, Oregon
Olympia, Washington
Seattle, Washington
Wenatchee, Washington

Mailing address: Pacific Northwest Forest and Range
Experiment Station
P.O. Box 3141
Portland, Oregon 97208

GPO 991-505

The FOREST SERVICE of the U. S. Department of Agriculture is dedicated to the principle of multiple use management of the Nation's forest resources for sustained yields of wood, water, forage, wildlife, and recreation. Through forestry research, cooperation with the States and private forest owners, and management of the National Forests and National Grasslands, it strives — as directed by Congress — to provide increasingly greater service to a growing Nation.